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Lightweight HMMWV Armored Doors: A Detailed Approach of the Fabrication Process

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14. ABSTRACT

The need for improved, lighter weight vehicles and equipment will almost always be a key issue with Army systems. Unfortunately, other countries are improving their weapon systems and techniques in parallel with this effort, as is evident in this latest conflict. Therefore, Soldiers have to adapt “on the fly” and are reinforcing the armor on their vehicles in the field. This is providing the needed protection but is expediting the wear and tear of vehicles and shortening their life expectancies. Thus, a lightweight armor solution was needed that provided the necessary protection as well as reducing the load on the vehicles. This report investigates hybrid solutions for reinforcing the armor on air assault ground mobility vehicles.

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Contents

List of Figures

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1. Introduction

The current operations in Iraq, where open war fields have turned into urban war fields, have created the need for lighter, more mobile, armored vehicles. The fighting is now taking place on city streets and roadways where the maneuverability and tactics of a lightweight vehicle are more desirable. The U.S. Army is suddenly faced with the need to armor these tens of thousands of tactical and logistic vehicles, such as high mobility multipurpose wheeled vehicles (HMMWVs) and trucks, against threats such as roadside bombs and suicide bombers. One such vehicle is the air assault ground mobility vehicle (AAGMV), an armored HMMWV used to transport a nine-person light infantry squad onto the battlefield. Current techniques for reinforcing armor are overloading such vehicles and are significantly reducing their effectiveness, as well as expediting part lives. The objective of this program is to reduce the weight of the armor by as much as 30% while maintaining the same or higher protection levels.

2. Approach

For this program, armor schemes that worked well for similar threats in the past (*1*, *2*) were investigated. One material that performed so well for programs such as the Bradley infantry fighting vehicle was a 24-ounce S-2 woven glass that was pre-impregnated with Cycom 4102 polyester resin (Cytec, Inc.). This would be the basis for developing "recipes" for the particular door application addressed in this report.

3. Procedure

In order to meet the desired protection level (*3*) and availability of material, high hard (HH) steel was used in conjunction with composite. The main function of the HH steel was to break up[1] the projectile, thus significantly reducing the velocity and effectiveness. The purpose of this report is to explain the procedure for processing the armor, not the actual function of the armor.

A procedure was developed for bonding the composite panels to the steel door, which was already in its intended end use state. By that, we mean that all cut-outs for the steel were already established, brackets were attached, and the piece was curved.

[1]Break up as used in this report means to reduce to pieces or components.

There were a couple of methods of producing this armor, the first being to cure and bond the composite onto its mated steel part with an adhesive layer between the two materials. This worked reasonably well, but quality was sacrificed when the plies were worked around brackets. The other factor was the question of how well the stiff adhesive layer will behave during vehicle vibration during missions. Both methods are touched upon in this report. The chosen method would be to use the HH steel as a mold for which to cure the composite but not to bond it to the steel. Therefore, a secondary step would be necessary: using a polysulfide adhesive for bonding. The following procedure was used to produce the armor, and each step is explained in more detail on the following pages.

- Cutting the pre-impregnated (prepreg) S-2 glass/4102 resin,
- Placing plies at the desired thickness,
- Preparing the HH steel for curing of the composite,
- Vacuum bagging and curing the composite panel(s),
- De-bagging the composite panel(s),
- Preparing the composite panel for bonding,
- Preparing the HH steel for bonding,
- Applying adhesive and vacuum bagging for bond cure, and
- De-bagging of hybrid solution and installing weather stripping in preparation for "rhino lining[2]".

3.1 Cutting the Prepreg

The prepreg material is stored in a freezer, and its temperature needs to be raised to room temperature for the prepreg material to be cut. At times, it may be more practical to cut the material while still cold to avoid high tackiness, which is somewhat of a nuisance with cutting wheels and handling. The prepreg, placed release side down, was cut on an automated table with vacuum capability for holding the material in place during cutting. The Gerber 2600 automated table was used for all material cutting (see figure 1). If an automated table is not available, the material can be cut by hand with shears or cutters. The cutting table was programmed to exactly duplicate the size and shape of the steel with additional cut-outs added for welded brackets, window attachment points, etc.

3.2 Laying of Glass Plies

The protective release film was removed from each ply before placement. The cut plies are then laid or placed on top of one another in perfect alignment (see figure 2). Being a woven roving (0/90) material, the stacking sequence provides a simple orthotropic composite. Notice the cut-

[2]Rhino lining is the method that the automotive industry currently uses to line truck beds. It is a specially formulated polyurethane that is sprayed onto the bed at a certain thickness.

outs that were programmed into the cutting table. The prepreg material becomes tacky as it is warming, so it is best to have two people placing the plies onto a flat, clean surface (glass tables work nicely). Otherwise, proper alignment of plies becomes tricky because of tackiness, and once a ply is placed on the previous ply, removal is difficult. All material handlers should be wearing personal protective equipment (gloves, safety glasses, etc.) to prevent resin from getting on their skin and to prevent the resin from becoming contaminated with skin oils. Frequent glove changes are recommended as the prepreg becomes tackier.

Figure 1. Automated cutting table.

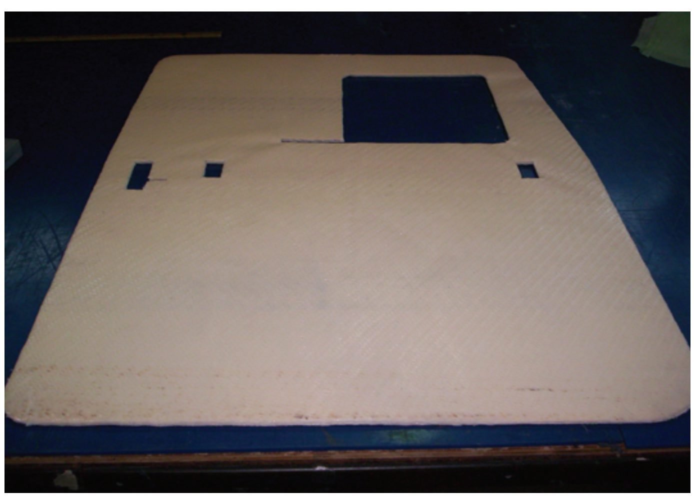

Figure 2. Prepreg plies laid.

3.3 Preparation of HH Steel for Curing Composite

The actual HH steel door was used as the mold for curing the composite. The authors prepared the steel surface for molding by first cleaning with acetone or other degreasing agent to remove any cutting fluids or impurities that may have been left from manufacturing. The HH steel was then treated with two applications of a liquid mold release agent (Frekote[3] 77 NC) to prevent the part from bonding to the mold (in this case, the HH door) during cure. After the Frekote application, a layer of non-porous Teflon[4] (200TFNP-coated fiberglass) was cut to match the same shape as the door and the S-2 and was placed on the HH steel. This is an additional release layer to ensure that the part does not bond to the door. The S-2/4102 ply stack was then placed on the TFNP and door. In any area where the resin is not intended to be, such as the bracketed areas, layers of tacky tape (Schnee Moorehead 5126, 0.5-inch by 0.125-inch sealant tape) were applied to prevent any possible resin flow into that void during cure. Also a layer of high temperature blue flash breaker tape was placed around the mounting brackets on the door where there is a possibility of contact with the prepreg (see figure 3). The figure shows the alternate method with FM93 adhesive for the bonding step.

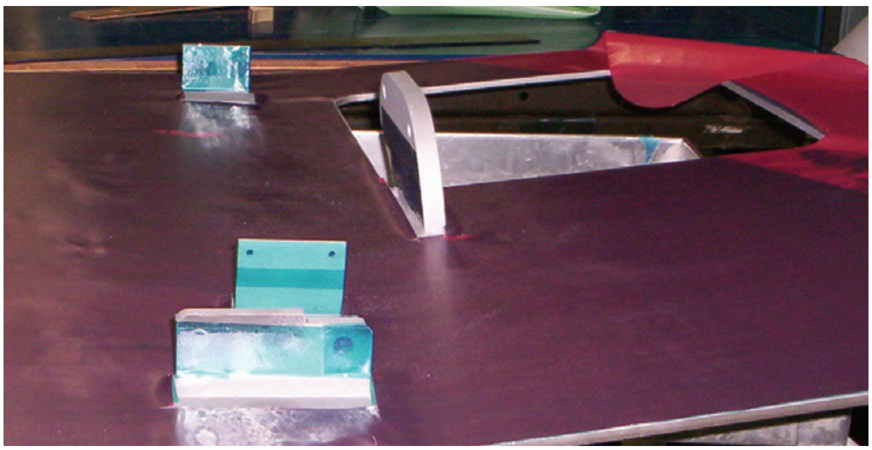

Figure 3. Flash tape placed on brackets.

Once the plies were laid onto the door, it was wrapped in a layer of nylon release fabric (A888 peel ply) for ease of part separation after cure. A layer of N10 poly-breather fabric was wrapped around the door as well. The breather is needed to obtain good vacuum pressure. Additional layers of N10 breather were folded and placed around all areas of the door that had any protruding hardware. The folded layers served two purposes. First, they serve as additional protection to the bag so that under vacuum, the brackets do not puncture the bag. Second, they prevent any bridging of the bag around the brackets that would cause poor consolidation and wrinkling of the S-2 panel—an undesired effect. The door is now ready for the bagging stage.

[3]Frekote is a registered trademark of Henkel Loctite Corporation.
[4]Teflon is a registered trademark of E. I. DuPont de Nemours & Co., Inc.

3.4 Vacuum Bagging and Curing of the Composite Panel(s)

The bagging material selected for this panel was an extruded nylon tube bag that can withstand temperatures as high as 400 °F. The panel, plies, and door were placed into the bag, which was open on opposite ends, and cut to the appropriate length to leave excess bag on each end for sealing. The placement of the door into the bag was done in a delicate manner so as not to perforate the bag in any way. A vacuum gland (Air Tech) that could be quickly disconnected was sealed through the bag to the side of the part and was placed on an additional layer of N10 breather that also extended to be in contact with the wrapped door (see figure 4). The gland is a two-part device, a base and a quick disconnection, where the base is sealed inside the bag and a slit is cut into the bag in order to attach the disconnect to the base. Both ends of the bag were then sealed with tacky tape or a heat sealer. Once sealed, the gland is attached to a vacuum pump via a hose, and all the air is removed from the bag. During this air evacuation stage, enough slack must be allowed in the bag around the brackets and other protruding areas so as not to cause bridging or rupturing of the bag.

After the bag was sealed and verified to have no leaks, it was carefully loaded into an oven while still under vacuum and the entire assembly was cured under pressure. It is necessary to maintain vacuum during the entire cure cycle, including the cooling period. The cure used was

Gradually increase at 4 °F/min to 150 °F,

Soak for 1 hour;

Gradually increase at 4 °F/min to 250 °F,

Soak for 3 hours.

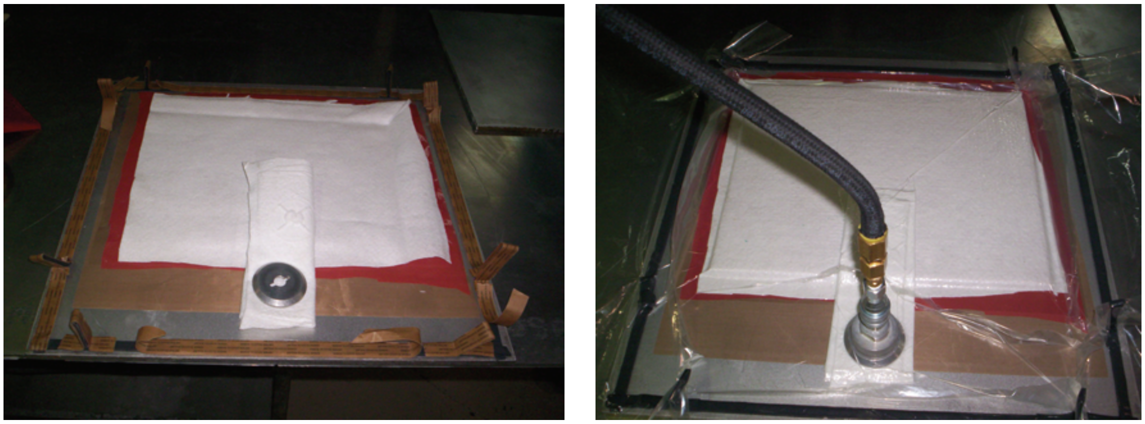

Figure 4. Example of additional N10 breather for gland.

After the 3-hour soaking at 250 °F, the oven was turned off to allow the part to cool to room temperature; vacuum was maintained through the entire cycle.

3.5 De-bagging of the Composite Panel(s)

After curing, the vacuum was disconnected and the panel was separated from the bag, breather, and release plies. The cured panel was then removed from the door fixture and prepared for adhesive bonding. Figure 5 shows the cured composite separated from the mold. Of course, if the adhesive method were used, the cured composite would be permanently attached to the door at this point.

3.6 Preparation of the Composite Panel for Bonding

For permanent bonding, the S-2 glass panel was sanded on all edges to remove any resin flash that occurred during curing, and all bracket holes were cleaned and reshaped with a grinder to proper size. The back of the panel (the side that was in contact with the tool surface) was either sanded or grit blasted to remove any release agent that may have contaminated the surface during the process.

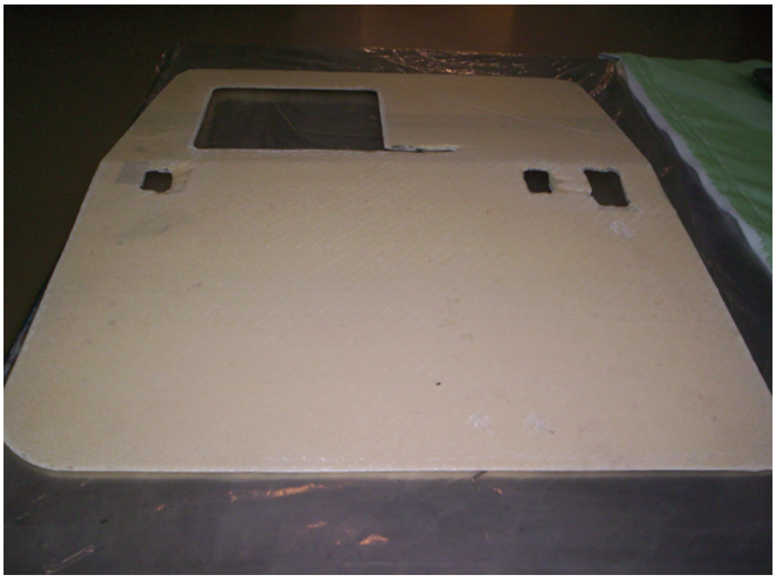

Figure 5. Cured composite after de-molding.

3.7 Preparation of the HH Steel for Bonding

The HH steel was also grit blasted with a 70- to 180-grit abrasive alumina grit to remove any resin film and the release agent that was applied. Once the entire door surface was decontaminated, it was spray cleaned with only filtered compressed air or nitrogen to remove any of the blast media. It was then acetone washed and ready for bonding. Figure 6 shows the door after being grit blasted, acetone washed, and ready for bonding stage.

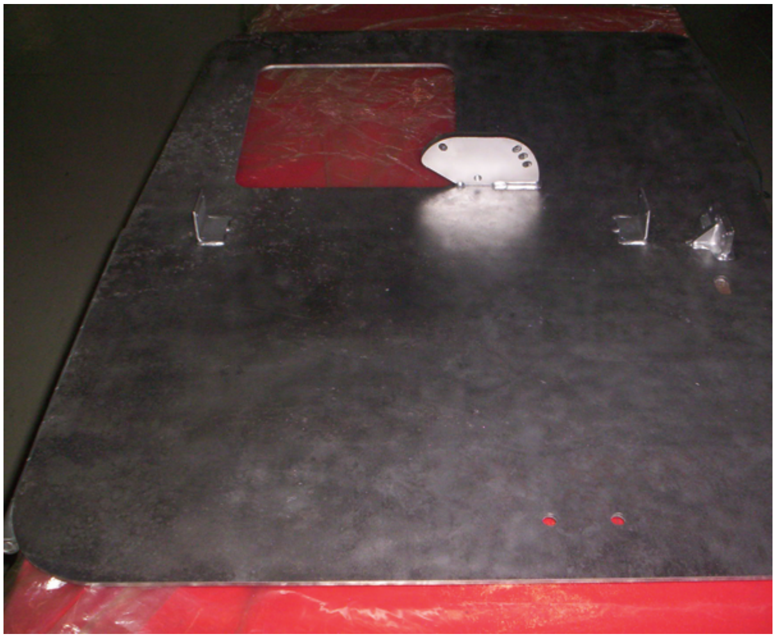

Figure 6. Prepared door for bonding.

3.8 Application of Adhesive and Vacuum Bagging for Bond Cure

Both the S-2 glass and the HH steel are prepared for the polysulfide adhesive. Polysulfide is a two-part adhesive that is mixed accordingly to a 10-to-1 ratio by weight of adhesive (A) to catalyst (B). The adhesive was mixed by hand until there was a consistent uniform color: charcoal gray. We ensured that there were no distinct color traces of either of the two parts (part A-white, part B-black). The adhesive was poured onto the HH steel, allowing for pooling, and then spread evenly over the entire surface with mixing sticks (see figure 7). The photograph is used just for showing the method and is not an actual door.

A series of nylon shims was then randomly placed over the surface with approximately 8 to 10 inches between each. The shims, which in this case were 0.020-inch-thick fishing line, act as gauges for the bond-line thickness between the HH steel and the S-2 panel. With the HH steel now fully covered with the polysulfide, the S-2 glass panel was placed over the door, and bracket holes and edges were carefully aligned, thus merging the two pieces together. Again, the areas where it was desired not to have any S-2 glass around the brackets were cleaned, and tacky tape was applied to create damming. The door was then completely wrapped in a layer of release fabric (A888); no area was left exposed. A layer of N10 breather was applied in the same manner as previously mentioned, which completely wrapped the door. The door was then placed into the nylon tube bag that was cut to size; the bagging material was not perforated. The quick disconnect vacuum gland was placed on the bag over a layer of N10 which was also in contact with the door. Both ends of the bag were sealed with tacky tape. The bag was then connected to a vacuum source via the gland and air was removed from the bag, compressing the S-2 glass panel and HH steel together. The excess adhesive was squeezed out along the edges but contained in the release fabric

or peel ply. The part was then left to cure at room temperature for 36 hours, under vacuum. The cure time could be reduced if an oven were used at an elevated temperature. Polysulfide can be cured at 125 °F for 12 hours, but the practice was a room temperature cure for this application.

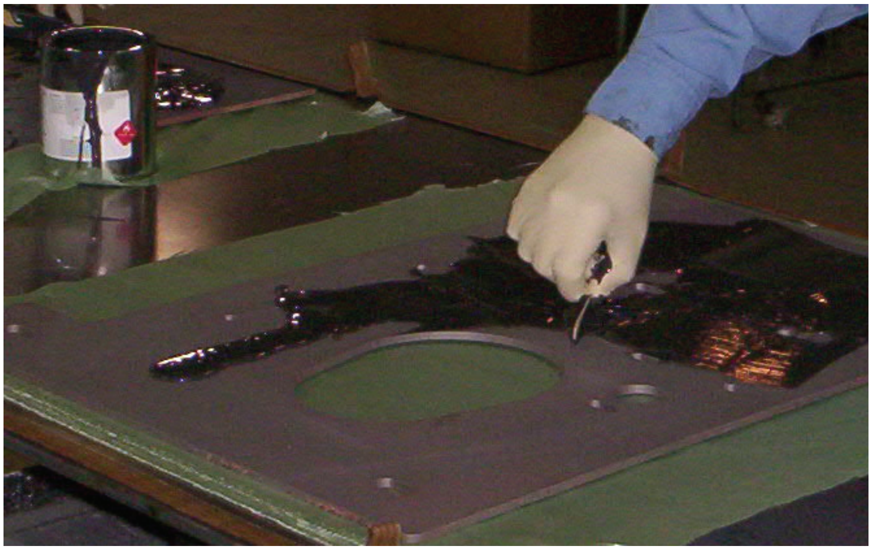

Figure 7. Spreading adhesive onto steel.

3.9 De-bagging of Hybrid Solution and Installing Weather Stripping in Preparation for Rhino Lining

The final de-bagging step is identical to step 5. Once the part was removed from the bag, it was cleaned of any excess adhesive that was squeezed out from between the steel and the S-2. The polysulfide is a rubbery adhesive after cure and can be easily removed with a sharp razor knife or scraper. Any tacky tape that was used to dam the adhesive from the bracketed areas was removed. The composite door is now ready for the installation of the weather stripping. The weather stripping is an extruded U-channel with a rubber gasket bonded on its edge, a Trim-Lok, Inc., product. For this application, the channel was placed over the edge of the door and tapped with a rubber mallet on the back until it firmly sat on the door panel. The gasket portion faced the S-2 panel side of the door. The gasket was applied as the worker tapped in place and moved around the edge until the two ends met. The gasket was cut to length with snips. The window cut-out of the door also required weather stripping and was installed in the same manner, except that the rubber gasket faced the exterior, the steel side, allowing the door window to close against it when installed. Figures 8 and 9 show the door before the rhino-lining step.

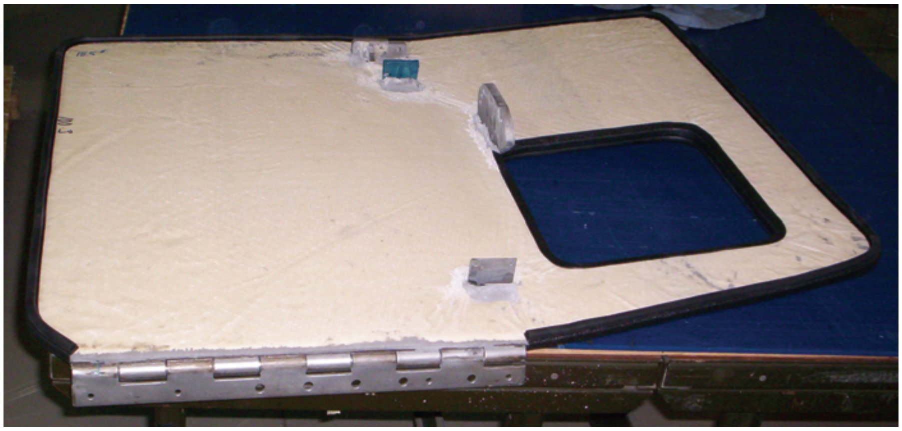

Figure 8. S-2 glass side of door.

Figure 9. Steel side of door.

4. Summary

The intent of this report was to provide details for the fabrication of a typical hybrid armor panel. It is more of a reference guide rather than a standard operating procedure. Some ensuing work was done on HMMWV body panels as well, and that report will be released in the near future.

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